NAMRL 1274

STIMULUS DETERMINANTS OF DYNAMIC VISUAL ACUITY

II. Effects of Limiting the Target Surround

James E. Goodson and Tommy R. Morrison

April 1981

NAVAL AEROSPACE MEDICAL RESEARCH LABORATORY
PENSACOLA, FLORIDA

Approved for public release; distribution unlimited.

STIMULUS DETERMINANTS OF DYNAMIC VISUAL ACUITY

II. Effects of Limiting the Target Surround

James E. Goodson and Tommy R. Morrison

Naval Medical Research and Development Command
ZF 51.524.004-2011
MR 041.01.03-0154

Office of Naval Research
RR 041.01.02 NR 201.038

Approved by

Ashton Graybiel, M.D.
Assistant for Scientific Programs

Released by

Captain W. M. Houk, MC, USN
Commanding Officer

9 April 1981

Naval Aerospace Medical Research Laboratory
Naval Air Station
Pensacola, Florida 32508

SUMMARY PAGE

THE PROBLEM

Differences among laboratories regarding the magnitude and linearity of the dynamic visual acuity (DVA) function appear to be due, in part, to variations in the configuration of the stimulus field surrounding the stimulus target. Available data do not provide an adequate basis for predicting the effects upon the DVA function of relatively simple variations in stimulus configuration. Clarification of effects of stimulus configurations surrounding the target is required if measures of DVA are to be standardized and applied to the prediction of individual capabilities, and to the development of criteria for the design of visual displays.

FINDINGS

Experiments were conducted to determine the effects upon DVA performance of limiting the illuminated area surrounding the target. Although no effect was observed when the target velocity was 20°/sec, the degradation in performance at 110°/sec was significantly increased when the target surround area was decreased. This velocity by surround interaction demonstrates the nonlinear effect upon the DVA function which may be incurred as a result of a relatively simple change in the target surround.

ACKNOWLEDGMENT

The authors wish to thank LT D. J. Blower, USN, for his counsel and assistance regarding statistical analyses.

Tommy R. Morrison's present address is Human Factors Engineering Division, Aircraft & Crew Systems Technology Directorate, Naval Air Development Center, Warminster, Pennsylvania 18974.

INTRODUCTION

Dynamic visual acuity (DVA) is a measure of ability to recognize moving targets during voluntary ocular pursuit. There is general agreement that acuity for a moving target is degraded as a function of the target's angular velocity with respect to the observer (1, 2). There is not general agreement regarding the causes and quantitative characteristics of this degradation. The confounding effects of individual differences, within-subject variability, and variations in apparatus and procedure among laboratories appear to obscure fundamental characteristics of the DVA function. Clarification is required if measures of this function are to be applied to the assessment and prediction of individual capabilities for visual performance, and if the understanding of this function is to influence task design.

BACKGROUND

Goodson and Morrison (3) have discussed problems in identifying the causes of degradation of DVA and in interpreting the DVA function from existing data. It appears that differences in results among laboratories have resulted, in part, from undefined differences in stimulus conditions under which data were obtained. Although few parametric data are available to describe the effects of stimulus variables upon DVA, some appreciation of the complexity of stimulus interactions may be obtained in considering the sorts of variables which have been documented to affect the performance of component, or closely related, tasks, such as static acuity, detection, and visual pursuit.

The recognition of a visual acuity target, when observed under stable conditions, is affected by target type (4-6), contrast (7-9), luminous intensity (10, 11), extent and relative luminance of the surround (12, 13), proximal contours (14, 15), and position in the visual field (16, 17). When these variables are allowed to covary, their effects are compounded. Interactive effects have been demonstrated for target type and luminance (11, 18), luminance and retinal position (19), surround luminance and target luminance (12, 13), and size and contrast (20-23). Acuity performance is further affected by dynamic characteristics of stimulus-response interactions that occur as a function of exposure duration (24-26), temporal changes in luminance (27, 28), and image movement on the retina (29, 30).

The DVA task is more complicated than the static acuity task in that it challenges the observer to detect a target as it traverses the field of view, visually acquire it by one or more successions of saccadic and smooth pursuit eye movements, and resolve some critical detail contained in it, all within a relatively brief time period. The effective exposure time, contrast, position, and movement of the target image on the retina depend upon the latency and accuracy of the observer's visual and oculomotor responses to targets in motion.

It appears that the ability to perform these dynamic visual and motor functions in response to rapidly moving targets varies independently of the ability to recognize targets which are stationary or moving at low angular velocities. Correlations between static visual acuity and DVA decrease as the DVA target velocity is increased (31-34). Large individual differences in DVA are observed among subjects whose static visual acuity is 20/20, or better (35, 36). And, one subject may demonstrate much poorer acuity than another for targets moving at 20°/sec, but perform much better than the same subject for targets moving at 110°/sec (1, 37).

Ocular pursuit required for the DVA task is accomplished by combinations of saccades and smooth pursuit eye movements. It is thought that saccadic and smooth pursuit systems are at least partially independent (38, 39), and that the function of saccadic movements is to correct position error while that of smooth pursuit movements is to reduce the velocity of a target image on the retina (40). Saccadic eye movements in response to a moving target occur with latencies of 200-250 msec (29, 40), depending to some extent upon target luminance (41) and velocity (40, 42). The latency for smooth pursuit movements is about 125 msec, and the limiting speed for accurate, smooth pursuit tracking is usually stated to be 25-30°/sec (39, 40). However, Atkin (43) has suggested that this limit depends upon the nature of the tracking task. When his subjects were required to detect changes in the stimulus during ocular pursuit, some exhibited smooth pursuit movements upwards of 100°/sec. Reading's (44) subjects exhibited accurate smooth pursuit movements in response to acuity targets moving at velocities up to 43°/sec, but their responses to higher target velocities (83 and 163°/sec) were less accurate and included increasing evidence of saccadic corrections. It is not clear to what extent the smooth pursuit during these tracking tasks is under stimulus control, and to what extent task repetition allows anticipatory pursuit movements (40, 43).

When pursuit movements are under stimulus control, it appears that the magnitude of the initial saccade and the velocity of the subsequent smooth pursuit movement are determined prior to the initiation of the respective movements, that subsequent corrections are made by means of new saccades and either the same or new pursuit velocities with characteristic latencies (40), and that the magnitude of both position and velocity errors increases with increased target velocity (40, 42, 44).

PROBLEM

Differences among laboratories regarding the magnitude and linearity of the DVA function appear to be due, in part, to variations in the configuration of the stimulus field surrounding the acuity target (3). Although surround configurations frequently are not well specified in DVA reports, large variations may be inferred from descriptions of the subject viewing the target through microscope optics versus a rotating mirror versus directly viewing the target moving across a tangent screen versus a cylindrical screen.

The uncertain correlation between static acuity and DVA performance suggests that the acquisition abilities, required for detection and visual pursuit, may vary independently of resolution abilities. Indeed, Ludvigh (45) and Ludvigh and Miller (35) have argued effectively that the major cause of degradation in DVA is the decreased ability to reduce image motion on the retina during ocular pursuit of the higher velocity targets. To the extent that characteristics of the adequate stimulus for each of these component tasks are different, it is expected that variations in stimulus configurations could differentially affect recognition versus acquisition performance, and thereby differentially affect DVA performance at low versus high target velocities.

Available data do not provide an adequate basis for predicting the effects upon the DVA function of relatively simple variations in stimulus configuration. A case in point is that of limiting the illuminated area surrounding the acuity target. One would predict that recognition of a stationary target would be degraded by such a limited surround due to spatial interactions related to border effects and differential adaptation across the retina. Similar effects would be predicted for the recognition of a moving target during perfect pursuit. Imperfect pursuit of a moving target would add a transient characteristic to the proximal stimulus so that the effects of the limited surround would be to degrade recognition performance even more. However, it is suggested that the delimited surround would provide additional stimuli for detection and tracking, and thereby enhance acquisition performance. The relative strengths of these effects are unknown. The immediately relevant data are addressed in the following paragraphs.

It is clear that both detection and acuity thresholds for a stationary target are affected by the stimulus configuration surrounding the target stimulus. Fisher (13) corroborated the earlier results of Lythgoe (12), finding that static visual acuity is decreased when the luminance of the field surrounding a 2° target area is decreased significantly below that of the target area. Flom et al. (14) demonstrated that acuity for a Landolt ring is degraded by the placement of surrounding dark bars near the target. The maximum target-to-bar distance associated with degradation in acuity was proportional to the threshold gap size. Similar spatial interaction effects have been reported by Craig (15) for the detection of a gap in a horizontal line when parallel bars were placed near the gap. Novak and Sperling (46) reported degradation in detection of a small disc near a bar to be time dependent, requiring more than 10-msec exposure time to begin its development. Rousseau and Lortie (47) reported a time dependent facilitation effect for the detection of a line between two dark bars when the distance between target and bars was 1°3', and degradation in detection performance as the bars were moved closer to the target line. Westheimer (48) found that the scotopic increment threshold for a small, flashing disc was progressively raised by increasing the size of a surround disc up to 45 minutes of arc. Under conditions of partial light adaptation, the continued growth of the surround disc lowered the increment threshold once more. He observed a similar spatial interaction for cone vision (49), where the critical surround size was 5 minutes of arc arc in the foveal area, and increased with distance away from the fovea. Westheimer and Hauske (50) demonstrated that vernier acuity is degraded by the presence of either horizontal or vertical lines near the acuity target, the maximum interference occuring when the lines are separated from the vernier target by 2 to 5 minutes of arc.

Velocity error during the ocular pursuit of a moving DVA target adds a transient characteristic to the proximal stimulus. The movement over the retina of a target image embedded in a concentric disc of light would stimulate transient adaptation along the path of the disc. In the case of static acuity, the requirement for adaptation during target exposure appears to be detrimental. Craik (28) reported photopic acuity for a parallel line target to be degraded when the luminance during target exposure was significantly different from the adaptation luminance. Boynton and Miller (27) presented briefly a letter target 0.3 sec after a sudden change in background luminance, and found that the contrast required for letter recognition increases as a function of the magnitude of the luminance change.

Although the effects of limiting the target surround upon the recognition task in DVA would appear to be negative, the effective increase in cues for acquiring the target would appear to be beneficial to DVA performance. The available data which are most relevant to this point concern luminance thresholds for the detection of the presence and direction of movement of rapidly moving targets. Pollock (51) obtained luminance thresholds for the detection of a 1° light disc moving over a 20° arc in a dark field at velocities up to 2000°/sec. He found that the log luminance of the disc required for detection varies as a linear function of target velocity. Detection thresholds for vertical movement were slightly lower than those for horizontal movement as is the case for recognition thresholds in DVA (52). A similar linear relationship for the detection of moving stimuli was reported by Brown (53, 54) and Johnstone and Riggs (55). In addition to detection thresholds, those authors determined thresholds for identifying the direction of stimulus movement. Brown (53, 54) moved a disc which subtended 1.8 minutes of arc along horizontal paths of 1.7, 5.2, 17, and 53 minutes of arc at velocities up to 51°/sec. He found that direction thresholds agreed approximately with detection thresholds at lower stimulus velocities but diverged upward as a limiting stimulus velocity between 30° and 40°/sec was approached. Johnstone and Riggs (55) moved a 12° by 3° luminous rectangle over a 6° path at rates varying from 80° to 640°/sec. The luminance thresholds for both detection and direction appeared to agree at 80°/sec and to diverge as two linear functions of velocity for velocities up to 640°/sec.

The only data which address directly the effects of target surround upon DVA were reported by Goodson and Morrison (3) as a result of a series of exploratory experiments. Their data suggest that DVA performance is degraded by restricting the area of the target's luminous surround.

The purpose of the present paper is to report two experiments regarding the effects upon DVA performance of limiting the target surround. The first experiment is exploratory in nature and provides data upon which to base the selection of an experimental surround configuration. The second experiment provides data for testing hypotheses regarding the effects of a limited target surround upon 1) DVA at 20°/sec, 2) DVA at 110°/sec, and 3) the DVA function over this velocity range (interaction).

METHOD

APPARATUS

Subjects viewed Landolt ring targets monocularly through a plane, front surface mirror 10.2 cm high and 25.4 cm wide, which rotated in a counterclockwise direction about a vertical axis along its midline. The mirror was driven by a variable speed motor to provide desired angular rates. Target exposure was controlled by a rectangular aperture in a flat white mask attached to the mirror. The aperture height was 2.54 cm. Its width was defined empirically to allow 0.4-sec exposure for each angular velocity. The distance from center of rotation of the mirror to the eye was 19.5 cm, and to the target was 590.1 cm. The eye to mirror to target angle was 105°. The plane of incidence was perpendicular to the axis of mirror rotation. With this geometry, the mean angular speed of the target image with respect to the eye is 1.94 times the speed of mirror rotation (56).

Targets were presented against a seamless, white, cylindrical background screen of 550.1 cm radius, 75.3° azimuth, and 274 cm height. The center of the screen's curvature was coincident with the axis of rotation of the mirror. The geometry of the room limited the arc size of this screen. A supplementary, flat screen slightly overlapped the right edge of the cylindrical screen to extend the white background an additional 40° in azimuth. The near edge of the flat screen was 376 cm from the mirror. A circular hole of 19 cm diameter was cut in the cylindrical screen for target presentation. The center of the hole was 120 cm from the floor and 34.6° from the edge of the flat screen. A target holder was located directly behind the aperture. With a target in position flush against the back surface of the screen, the aperture was filled. Counterclockwise rotation of the mirror produced image movement from right to left. Under full screen illumination, the rotating mirror reflected a perceptually uniform surface over 116.3° visual angle, except for a faint vertical line at 41° and the target at 76.6° from the right edge.

A series of Landolt ring targets was produced on matte photographic print paper and mounted on fiberboard discs of 20.3 cm diameter. Target contrast ratio was -.91. ($C = \frac{L_T - L_B}{L_B}$, where L_T = target luminance and L_B = surround luminance). The series included 18 gap sizes ranging from 0.65 to 20.38 minutes of arc at a viewing distance of 609.6 cm.

In the first experiment to be reported, four luminance configurations were employed, providing different target surround areas (SA-1 through SA-4). Two of these were then selected for use in the second experiment. For SA-1, full screen illumination was provided by 750-watt tungsten lamps mounted in Berkey-Colortran broad flood luminaires. Intensities were adjusted by means of crossed polarizing sheets to produce a near uniform luminance level of

150.7 cd/m^2 (44 ftL) over 40° surrounding the target, with a fall off of 10 percent over the peripheral extent of the screen. For the remaining three luminance configurations (SA-2, SA-3, SA-4), a Kodak projector was employed to project areal images on the screen so that the target appeared at their center. SA-2 was a circular disc of 30.5 cm (1 ft) diameter subtending 2°52' visual angle. SA-3 was a rectangle 30.5 cm (1 ft) wide and 61.1 cm (2 ft) high which subtended 2°52' by 5°43'. SA-4 was a rectangle 122.0 cm (4 ft) wide and 61.0 cm (2 ft) high which subtended 11°25' by 5°43'. In each condition, luminance was controlled by cross polarizing filters to produce near uniform luminance of 150.7 cd/m^2 (44 ftL). Under these limited-surround conditions, the only illumination on the remainder of the screen was due to stray light, and provided luminances less than 0.1 cd/m^2.

PROCEDURE

Prior to each experimental session, the mirror drive was set for the proper speed, and the appropriate mirror aperture was installed to control exposure time of the target at 400 msec. Within any experimental session, target velocity and luminance condition remained constant.

All observers viewed the target with their right eye, their left eye being occluded by an eye patch. Observers were seated, and their eye position was aligned with respect to the mirror and target by use of an adjustable head and chin rest. The experimenter was stationed behind the screen in order to manage the targets. For each target presentation, the experimenter selected the appropriate target and placed it in position with the gap in one of eight orientations. Target size was contingent upon correctness of the previous response. Target orientation was determined from a partially random table. The observer made a forced choice verbal response corresponding to one of eight possible gap orientations. An up-and-down psychophysical method was employed in which the target size was increased after an incorrect response and decreased after a correct response. The size for which an incorrect response followed a correct response was used as an estimate of threshold.

EXPERIMENT 1.

During a series of exploratory experiments, Goodson and Morrison (3) obtained data which suggested that DVA performance may be degraded by limiting the size of the illuminated area surrounding the acuity target. In those experiments, the four surround configurations described in the previous section of this report were used. The purposes of the present experiment are to replicate those exploratory findings and to select the surround configuration to be used for tests of hypotheses regarding the nature of these effects upon the DVA function.

PROCEDURE

One male subject 26 years of age participated in this experiment. He demonstrated 20/20 static visual acuity without correction.

After a brief series of demonstration trials, DVA thresholds were obtained under each of the surround conditions in the following order: SA-4, SA-3, SA-2, SA-1. For each surround condition, thresholds were obtained first for a target velocity of 20°/sec, then at 124°/sec. If the subject did not respond correctly to the targets moving at 124°/sec, the target velocity was reduced to 80°/sec. Five thresholds were obtained at 20°/sec for each surround condition. Ten thresholds were obtained at the higher target velocity used for each condition, but only the last five were included in the analyses.

RESULTS

Means and 95 percent confidence intervals for each condition are presented graphically in Figure 1. These data appear to support earlier observations (3) that DVA performance is degraded by limiting the size of the target surround. Although this subject's responses to the larger surround condition (SA-4) were similar to his responses to the full screen condition (SA-1), it appears that the two smaller target surrounds (SA-2, SA-3) served to degrade DVA performance considerably. Indeed, when the horizontal dimension of the target surround was just under 3°, the subject was unable to demonstrate recognition for Landolt rings having gap sizes greater

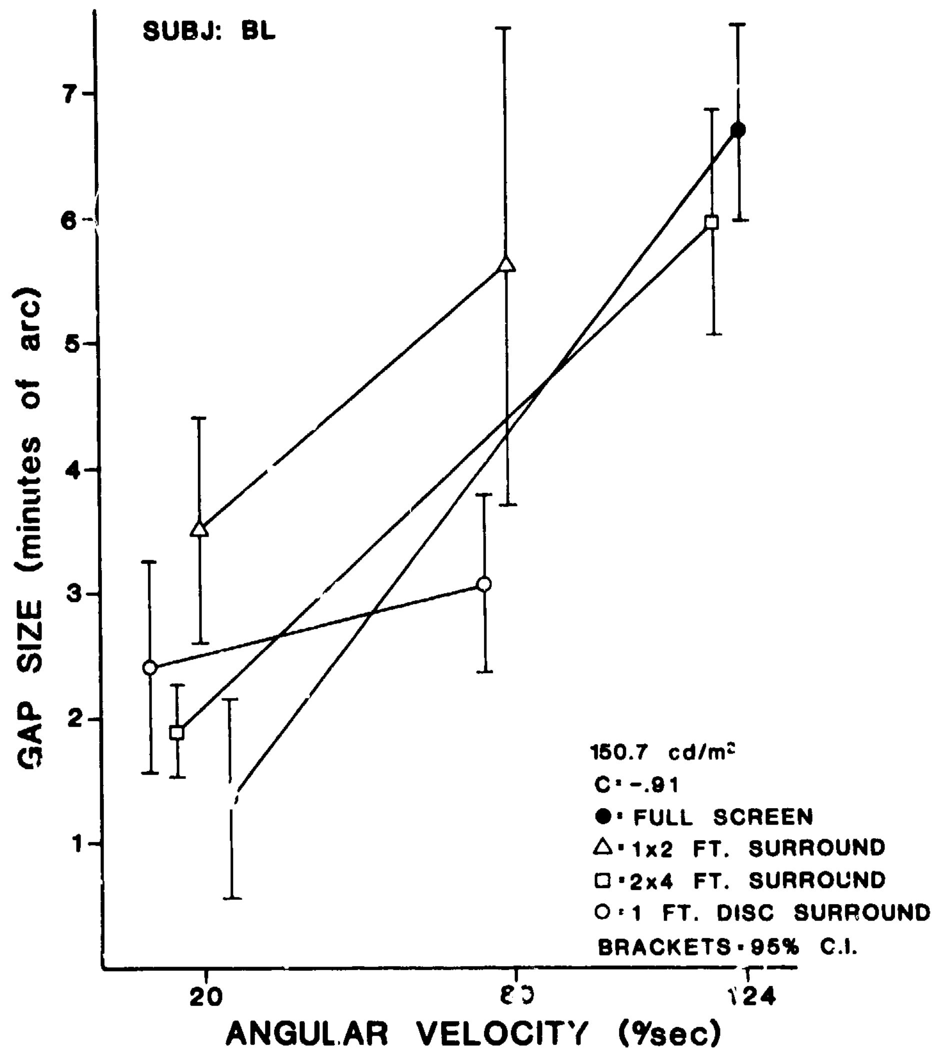

Figure 1. DVA of Subject BL for four target surrounds (● = full screen, △ = 2°52' x 5°43' rectangle, □ = 11°25' x 5°43' rectangle, ○ = 2°52' disc). Brackets indicate 95 percent confidence intervals (C.I.), C = contrast ratio.

than 20 minutes of arc when they were moving 124°/sec. Whereas, recognition thresholds of 6 to 7 minutes of arc were obtained at this speed when the larger surround or full screen illumination was used.

EXPERIMENT 2.

The exploratory data reported in the previous section suggest that the effects of restricting the size of the luminous field surrounding DVA targets tend to degrade rather than to enhance DVA performance.

The purpose of the present experiment is to test hypotheses of no difference in DVA performance when the target is presented in a large versus a small luminous surround.

PROCEDURE

Four male subjects between 20 and 26 years of age participated in this experiment. All subjects demonstrated 20/20 static visual acuity without correction.

The experiment employed two target velocities, 20°/sec and 110°/sec, and two surround conditions, SA-1 (full screen) and SA-3 (rectangular surround 2°52' wide by 5°43' high). For each surround condition, thresholds were obtained first for a target velocity of 20°/sec, then at 110°/sec. Two of the four subjects (LR, BF) were tested under surround condition SA-1 first, and two (DH, ZM) were tested under SA-3 first.

After a brief explanation and demonstration of the DVA task, ten thresholds were obtained for each of the four conditions. Only the last five thresholds were used for analysis, the preceding trials being counted as practice.

RESULTS

Means and standard deviations were calculated for the last five thresholds obtained for each subject under each condition. These are presented in

Table I. Means and 95 percent confidence intervals for each subject are presented graphically in Figure 2. Group means for each condition are presented graphically in Figure 3.

Table I

Effects of a Limited Target Surround Upon DVA
Means and (Standard Deviations) of DVA Thresholds (n = 5)
for Each of Four Subjects

	Angular Velocity			
	20°/sec		110°/sec	
	Surround		Surround	
Subject	SA-1	SA-3	SA-1	SA-3
DH	1.29 (0.22)	1.53 (0.17)	2.91 (0.70)	4.79 (0.46)
ZM	1.21 (0.35)	2.56 (0.71)	3.50 (1.08)	6.45 (0)
LR	3.75 (0.56)	3.47 (0.90)	4.96 (0.38)	5.66 (0.72)
BF	1.98 (0.20)	1.51 (0.63)	3.22 (0.35)	4.04 (0.68)

Tests of the _a priori_ hypotheses were performed by means of a two-way analysis of variance with repeated measures on both factors, and by contrasts between levels of the surround factor for each level of target velocity (57, 58). The results of these analyses are presented in Table II. Factor A is target velocity (20°/sec, 110°/sec), and Factor B is surround condition (SA-1, SA-3).

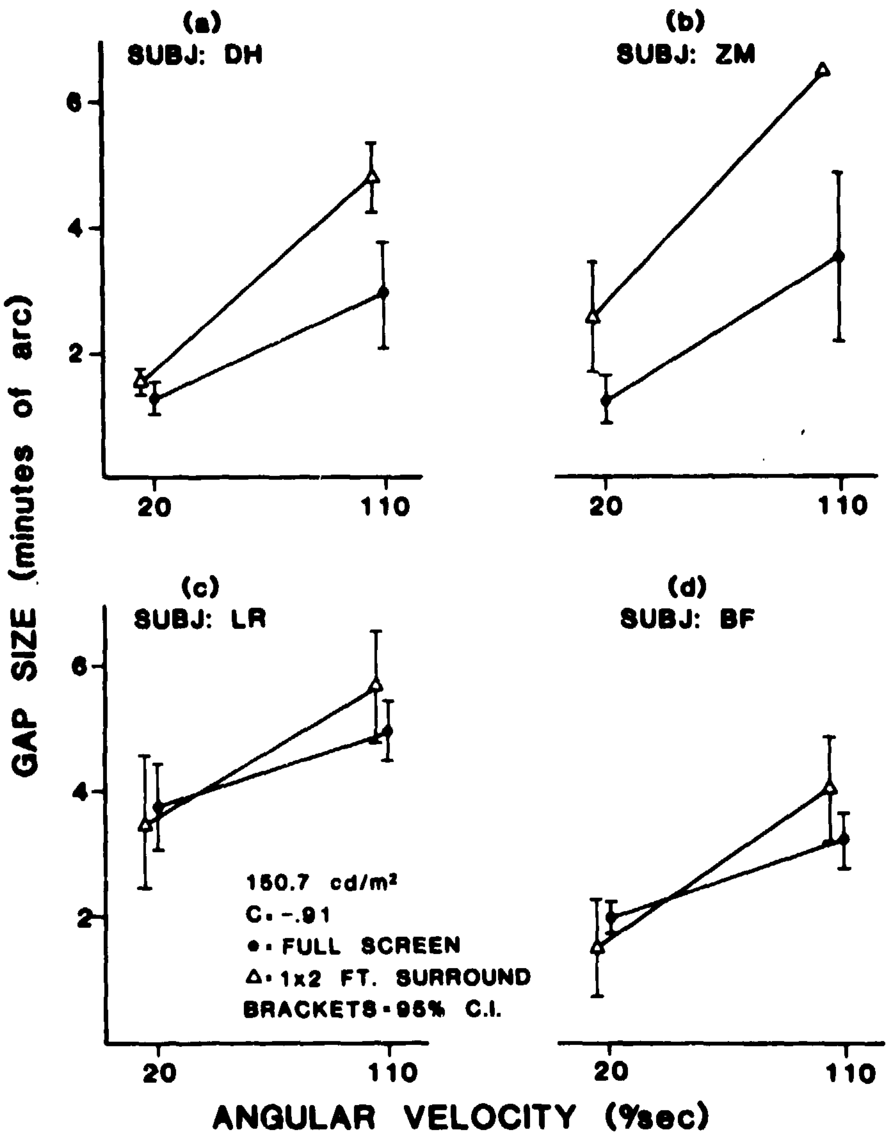

Figure 2. DVA of four subjects for two target surrounds (● = full screen, △= 2°52' x 5°43' rectangle). Brackets indicate 95 percent confidence intervals (C.I.). Confidence intervals < 0.5 are not plotted. C = Contrast ratio.

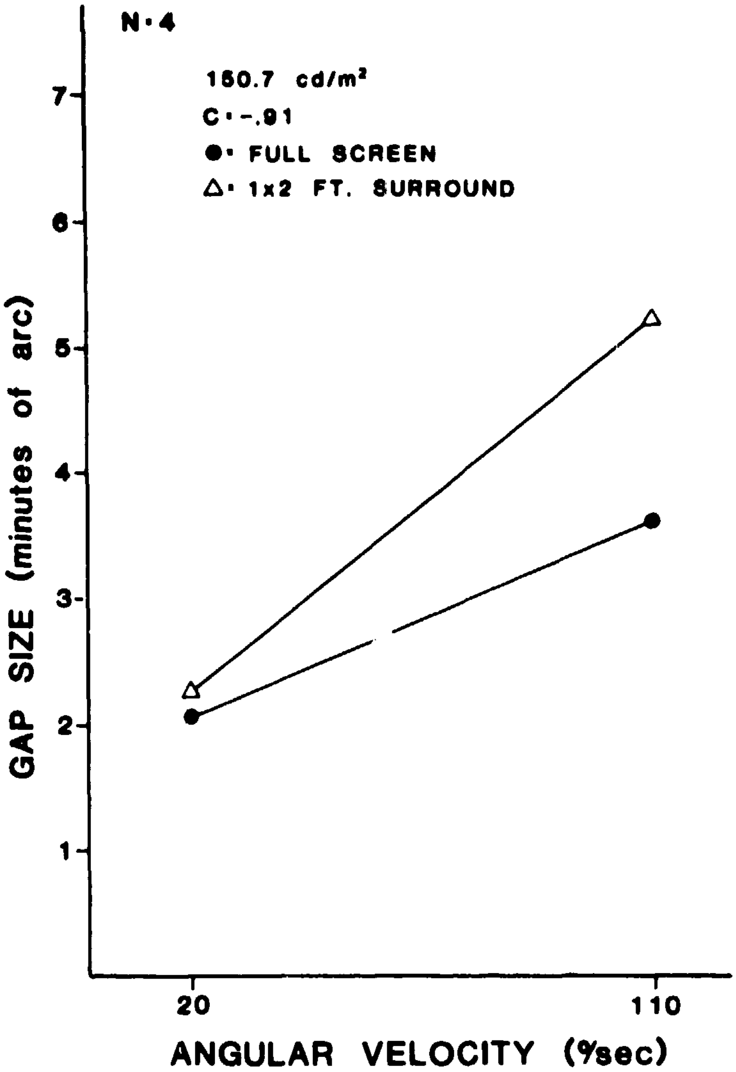

Figure 3. Mean DVA performance of four subjects for two target surrounds. (● = full screen, △ = 2°52' x 5°43' rectangle). C = Contrast ratio.

Table II

Two-way ANOVA (repeated measures) for Effects of Velocity Versus Surround Upon DVA

Source	F	df	α
A (Velocity)	53.07	(1,3)	.01
B (Surround)	3.74	(1,3)	N.S.
AB	80.15	(1,3)	.01
B_{A_1}	0.93	(1,2)	N.S.
B_{A_2}	53.17	(1,2)	.05

The significant F statistic for Factor A simply corroborates previous findings that DVA performance is degraded as a function of target velocity. The interpretation of the significant F obtained for the AB interaction is made apparent by reference to Figure 3; the effects of velocity upon DVA performance are greater for the limited surround condition (SA-3) than for the full screen condition (SA-1). The further contrasts indicate no difference between surround effects at the lower target velocity but a statistically significant difference between the effects of surround conditions at 110°/sec.

DISCUSSION

There is general agreement that the ability to recognize a moving target is degraded as a function of the target's angular velocity with respect to the observer. However, there is not general agreement regarding the causes and quantitative characteristics of this dynamic visual acuity (DVA) function. Reported variations in linearity, magnitude, and continuity of the DVA function may be due, in part, to variations in the configurations of the stimulus field surrounding the target. The surround configurations addressed in this paper involve the areal illumination surrounding the target. Relevant literature was discussed in the "Background" section for the purpose of developing a rationale for predicting the effects of these surround configurations upon DVA performance. Conflicting predictions appeared to be about equally supported by the existing literature, except for the one report of direct, if exploratory, observations by Goodson and Morrison (3).

Goodson and Morrison (3) measured DVA performance of two subjects under stimulus conditions similar to those of the present experiments. Their data have been replotted for presentation in Figure 4. The predominant characteristics of these data, as well as those presented in Figure 1, are the apparent degradation of DVA performance associated with an increase of target velocity and with a reduction of target surround, and the apparent interaction of surround and velocity effects. Based upon the data presented in Figures 2 and 3, hypotheses of no difference due to target surround SA-3 at 110°/sec and of no velocity-by-surround interaction were rejected. The basis for accepting the null hypothesis regarding surround effects at 20°/sec is tenuous. Of the seven subjects represented in these graphs, none performed better with the restricted target surround (SA-3) than with the full screen (SA-1) at 20°/sec, and three appear to have suffered degradation for at least one restricted surround condition. In any case, it seems clear that the restricted surround condition affects DVA performance more severely at 110°/sec than at 20°/sec and that the effect is detrimental.

The conclusion that DVA is degraded by restricted target surrounds for high target velocities more than it is for low velocities is puzzling in view of the a priori arguments. By and large, the arguments leading to a prediction of degraded performance were based upon experiments using static target presentations, while the literature relevant to the dynamic characteristics of the DVA task was interpreted to predict an enhancing effect by the surround borders. The fault in these arguments is not apparent to the authors, even in light of the present data. It is suggested, therefore, that 1) the characteristics of spatial and temporal summation which appear to degrade responses

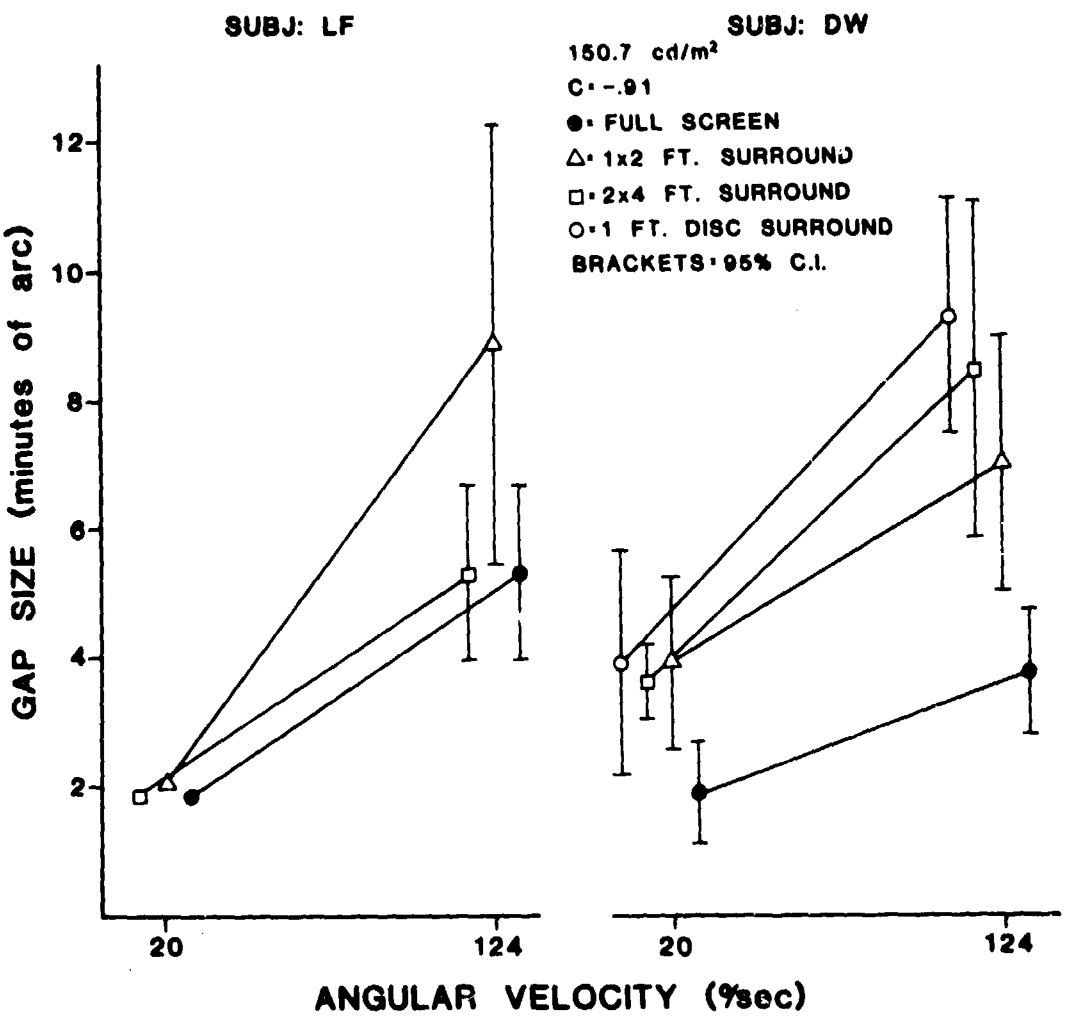

Figure 4. DVA of two subjects for different surround conditions. (● = full screen, △ = 2°52' x 5°43' rectangle, □ = 11°25' x 5°43' rectangle, ○ = 2°52' disc). Confidence intervals < 0.5 are not plotted. Redrawn from Goodson and Morrison (3).

to static targets are even more detrimental to the recognition of dynamic targets, and 2) that this detriment is greater than the enhancing effects of the increased acquisition cue provided by the circumscribed target surround.

In their exploratory data concerning the effects of contrast, luminance, and surround upon DVA performance, Goodson and Morrison (3) observed several occasions in which a practice or order effect seemed to be suggested. The possibility of such effects appears in the present data as well. From Figure 2, it appears that the effects of the surround condition are greater for subjects DH and ZM than for subjects LR and BF. DH and ZM were tested under the surround condition first, whereas LR and BF had considerable experience with the full screen condition before being tested with the limited target surround. Although by no means conclusive, these data prompt the question whether practice under the more favorable stimulus condition serves to reduce the detrimental effects of the limited target surround.

The argument was presented earlier that the DVA function (degradation of DVA as a function of target velocity) reflects visual acquisition ability rather than a degradation of the ability to recognize a target during visual pursuit. It was further argued that acquisition abilities may vary independently of abilities to resolve and/or recognize a target, that the sensory-motor mechanisms required for visual acquisition are at least partially independent of those required for visual recognition, and that the adequate stimulus for acquisition may be differentiated from that for resolution, and therefore may be independently manipulated.

The present experiments represent an effort to manipulate acquisition cues independently of resolution cues and thereby modify the rate at which DVA changes as a function of target velocity. Modification of the DVA function was accomplished by limiting the illuminated area surrounding the target. However, the effect was to increase, rather than decrease, the rate of degradation in DVA performance with target velocity. This result may be interpreted more easily in terms of a degradation in resolution or recognition than in terms of the "acquisition hypothesis." For example, the effects associated with transient adaptation may be increased by image movement on the retina.

The "acquisition hypothesis" might be tested more appropriately by providing borders around the target in a manner which does not require significant changes in adaptation level. This will be the subject of a subsequent experiment.

The present experiments demonstrate the ease with which DVA performance may be modified by altering the size of the target surround. The alterations used here are not extreme in comparison to variations which have been reported among laboratories. The need for defining standard apparatus and stimulus conditions for DVA testing is emphasized.

REFERENCES

1. Miller, J. W., and Ludvigh, E., The effect of relative motion on visual acuity. Surv. Ophthalmol., 7(2):83-115, 1962.

2. Morrison, T. R., A review of dynamic visual acuity. NAMRL Monograph 28. Pensacola, Fla.: Naval Aerospace Medical Research Laboratory, March 1980.

3. Goodson, J. E., and Morrison, T. R., Stimulus determinants of dynamic visual acuity. NAMRL-1270. Pensacola, Fla.: Naval Aerospace Medical Research Laboratory, August 1980.

4. The Adjutant General's Office, Dept. of the Army, Studies in visual acuity. PRS Rpt. No. 742, 1948.

5. Rabideau, G. F., Differences in visual acuity measurements with different types of targets. Psychol. Mono., 69(10):1-12, 1955.

6. Westheimer, G., The spatial sense of the eye. Invest. Ophthalmol. and Visual Sci., 18(7):893-912, 1979.

7. Cobb, P. W., and Moss, F. K., The relation between extent and contrast in the luminal stimulus for vision. J. Exp. Psychol., 10:350-364, 1927.

8. Ludvigh, E., Effect of reduced contrast on visual acuity as measured by Snellen test letters. Arch. Ophthalmol., 25:469-474, 1941.

9. Byram, G. M., The physical and photochemical basis of visual resolving power. I. The distribution of illumination in retinal images. J. Opt. Soc. Am., 34:571-591, 1944.

10. Hecht, S., A quantitative basis for the relation between visual acuity and illumination. Proc. Natl. Acad. Sci., 13:569-574, 1927.

11. Shlaer, S., The relation between visual acuity and illumination. J. Gen. Physiol., 21:165-188, 1937.

12. Lythgoe, R. J., The measurement of visual acuity. Series 173. Report of the Committee upon the Physiology of Vision, Privy Council Medical Research Council, HM Stationary Office, London: 1932.

13. Fisher, M. B., The relationship of the size of the surrounding field to visual acuity in the fovea. J. Exp. Psychol., 23:215-238, 1938.

14. Flom, M. C., Weymouth, F. W., and Kahneman, D. K., Visual resolution and contour interaction. J. Opt. Soc. Am., 53:1026-1032, 1963.

15. Craig, E. A., Proximal figure effects on visual acuity. Percept. and Motor Skills, 16:385-388, 1963.

16. Ludvigh, E., Extrafoveal visual acuity as measured by Snellen test letters. Am. J. Ophthalmol., 24:303-310, 1941.

17. Mandelbaum, J., and Sloan, L. L., Peripheral visual acuity. Am. J. Ophthalmol., 30:581-588, 1947.

18. Shlaer, S., Smith, E. L., and Chase, A. M., Visual acuity and illumination in different spectral regions. J. Gen. Physiol., 25:553-569, 1942.

19. Kerr, J. L., Visual resolution in the periphery. Percept. and Psychophysics, 9:375-378, 1971.

20. Kahneman, D., Temporal summation in an acuity task at different energy levels - a study of the determinants of summation. Vision Res., 4: 557-566, 1964.

21. DePalma, J. J., and Lowry, E. M., Sine-wave response of the visual system. II. Sine-wave and square-wave contrast sensitivity. J. Opt. Soc. Am., 52:328-335, 1962.

22. Campbell, F. W., and Green, D. G., Optical and retinal factors affecting visual resolution. J. Physiol., 181:576-593, 1965.

23. Ginsburg, A. P., Relating detection and identification of Snellen letters to the spatial filtering characteristics of the human visual system. Paper presented at 50th Annual Scientific meeting of Aerospace Medical Association, Washington, D.C., 14-17 May 1979.

24. Graham, C. H., and Cook, C., Visual acuity as a function of intensity and exposure-time. Am. J. Psychol., 49:654-665, 1937.

25. Keesey, U. K., Effects of involuntary eye movements on visual acuity. J. Opt. Soc. Am., 50:769-774, 1960.

26. Baron, W. S., and Westheimer, G., Visual acuity as a function of exposure duration. J. Opt. Soc. Am., 63:212-219, 1973.

27. Boynton, R. M., and Miller, N. D., Visual performance under conditions of transient adaptation. Illum. Eng., 58:541-550, 1963.

28. Craik, K. J. W., The effect of adaptation upon visual acuity. Br. J. Psychol., 29:252-266, 1939.

29. Westheimer, G., and McKee, S. P., Visual acuity in the presence of retinal-image motion. J. Opt. Soc. Am., 65:847-850, 1975.

30. Ludvigh, E., Visual acuity while one is viewing a moving object. Arch. Ophthalmol., 42:14-22, 1949.

31. Hulbert, S. F., Burg, A., and Mathewson, J. H., A preliminary study of dynamic visual acuity and its effect on motorists' vision. J. Am. Optom. Assoc., 29:359-364, 1958.

32. Burg, A., and Hulbert, S., Dynamic visual acuity as related to age, sex, and static acuity. J. Appl. Psychol., 45:111-116, 1961.

33. Burg, A., Visual acuity as measured by static and dynamic tests: A comparative evaluation. J. Appl. Psychol., 50:460-466, 1966.

34. Weissman, S., and Freeburne, C. M., Relationship between static and dynamic visual acuity. J. Exp. Psychol., 70:141-146, 1965.

35. Ludvigh, E., and Miller, J. W., Study of visual acuity during the ocular pursuit of moving test objects. I. Introduction. J. Opt. Soc. Am., 48:799-802, 1958.

36. Miller, J. W., and Ludvigh, E., The results of testing dynamic visual acuity of 1000 naval aviation cadets. NSAM-571. Pensacola, Fla.: Naval School of Aviation Medicine, 1956.

37. Ludvigh, E., and Miller, J. W., A study of dynamic visual acuity. NSAM-562. Pensacola, Fla.: Naval School of Aviation Medicine, 1953.

38. Rashbass, C., The relationship between saccadic and smooth tracking eye movements. J. Physiol., 159:326-338, 1961.

39. Robinson, D. A., The mechanics of human smooth pursuit eye movement. J. Physiol., 180:569-591, 1965.

40. Westheimer, G., Eye movement responses to a horizontally moving stimulus. Arch. Ophthalmol., 52:932-941, 1954.

41. Wheeless, Jr., L. L., Cohen, G. H., and Boynton, R. M., Luminance as a parameter of the eye-movement control system. J. Opt. Soc. Am., 57:394-400, 1967.

42. Crawford, W. A., The perception of moving objects. II. Eye movements. Report FPRC/Memo 150b. Farnborough, England: RAF Air Ministry Flying Personnel Research Committee, 1960.

43. Atkin, A., Shifting fixation to another pursuit target: Selective and anticipatory control of ocular pursuit initiation. Exp. Neurol., 23:157-173, 1969.

44. Reading, V. M., Analysis of eye movement responses and dynamic visual acuity. Pflügers Arch., 333:27-34, 1972.

45. Ludvigh, E., Visual and stereopsis acuity for moving objects. Proceedings of Symposium on Physiological Psychology. ONR Report ACR-1. Washington, D.C.: Office of Naval Research, 125-136, 1955.

46. Novak, S., and Sperling, G., Visual thresholds near a continuously visible or briefly presented light-dark boundary. Optica Acta, 10:187-191, 1963.

47. Rousseau, R., and Lortie, J. Y., Decrease and increase in target detection induced by adjacent borders. Percept. and Motor Skills, 31:483-488, 1970.

48. Westheimer, G., Spatial interaction in the human retina during scotopic vision. J. Physiol., 181:881-894, 1965.

49. Westheimer, G., Spatial interaction in the human cone vision. J. Physiol., 190:139-154, 1967.

50. Westheimer, G., and Hauske, G., Temporal and spatial interference with vernier acuity. Vision Res., 15:1137-1141, 1975.

51. Pollock, W. T., The visibility of a target as a function of its speed of movement. J. Exp. Psychol. 45:449-454, 1953.

52. Miller, J. W., and Ludvigh, E., Dynamic visual acuity when the required pursuit [illegible]ent of the eye is in a vertical plane. NSAM-563. Pensacola, Fla.: Naval School of Aviation Medicine, 1953.

53. Brown, R. H., The effect of extent on the intensity-time relation for the visual discrimination of movement. _J. Comp. Physiol. Psychol._, _50_:109-114, 1957.

54. Brown, R. H., Influence of stimulus luminance upon upper speed threshold for visual discrimination of movement. _J. Opt. Soc. Am._, _48_:125-128, 1958.

55. Johnstone, J. R., and Riggs, L. A., Upper-velocity threshold for detection of movement. _Optics Letters_, _4_:309-310, 1979.

56. Goodson, J. E., Dynamics of an image viewed through a rotating mirror. _J. Opt. Soc. Am._, _69_:771-775, 1979.

57. Kirk, R. E., _Experimental Design: Procedures for the Behavioral Sciences_. Belmont, CA: Brooks/Cole, 1968.

58. Winer, B. J., _Statistical Principles in Experimental Design_. New York: McGraw-Hill, 1962.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NAMRL- 1276	2. GOVT ACCESSION NO. AD-A10887?	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Stimulus Determinants of Dynamic Visual Acuity ... Effects of Limiting the Target Surround		5. TYPE OF REPORT & PERIOD COVERED INTERIM
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) James E. Goodson, CAPT MSC USN Tommy R. Morrison, LCDR MSC USN		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Aerospace Medical Research Laboratory Naval Air Station Pensacola, Florida 32508		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS ZF51.524.004.2011 MR 041.01.03.0154 RR 041.01.02.NR.201.038
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Medical Research and Development Command Navy Department, Washington, D.C.		12. REPORT DATE 25 November 1980
		13. NUMBER OF PAGES
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Tommy R. Morrison's present address is Human Factors Engineering Division, Aircraft & Crew Systems Technology Directorate, Naval Air Development Center, Warminster, Pennsylvania 18974.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Dynamic Visual Acuity
Visual capabilities
Visual performance
Visual acuity

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Differences among laboratories regarding the magnitude and linearity of the DVA function appear to be due, in part, to variations in the configuration of the stimulus field surrounding the stimulus target. Available data do not provide an adequate basis for predicting the effects upon the DVA function of relatively simple variations in stimulus configuration. Clarification of effects of stimulus configurations surrounding the target is required if measures of DVA are to be standardized and applied to the prediction of individual

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-LF-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) capabilities, and to the development of criteria for the design of visual displays.

Experiments were conducted to determine the effects upon DVA performance of limiting the illuminated area surrounding the target. Although no effect was observed when the target velocity was 20°/sec, the degradation in performance at 110°/sec was significantly increased when the target surround area was decreased. This velocity by surround interaction demonstrates the nonlinear effect upon the DVA function which may be incurred as a result of a relatively simple change in the target surround.